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(72) Inventor HELMUT FRIEDRICH

(54) AIRCRAFT POWER PLANT INCLUDING AUXILIARY ENGINE FOR DRIVING AIRCRAFT AUXILIARY COMPONENTS AND AN AIR-CONDITIONING UNIT

(71) We, VEREINIGTE FLUGTECHNISCHE WERKE-FOKKER Gesellschaft mit beschränkter Haftung, a Body Corporate organised and existing under the laws of the Federal Republic of Germany, of Hünefeldstrasse 1/5, 28 Bremen 1, Germany, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to aircraft power plant comprising at least one main gas turbine engine for propulsion of the aircraft and an auxiliary gas turbine engine having a connection to the main engine to receive compressed air from the main engine.

The auxiliary engine can be used for driving aircraft auxiliary components such as an electric generator and hydraulic pump and may also be used to supply compressed air via a compressor for starting of the main engine. In order to maintain the efficient operation of the auxiliary engine at high flight altitudes the latter is supplied with compressed air bled from the compressor of the main engine.

It is also known to interconnect the auxiliary engine with an air-conditioning system which is used for the supply of cool air to the cabin of the aircraft.

In accordance with the present invention there is provided aircraft power plant comprising at least one main gas turbine engine for propulsion of the aircraft, an auxiliary gas turbine engine having a connection to the main engine to receive compressed air from the main engine, a power-distributing transmission, and an air-conditioning unit drivable by the auxiliary engine through the power-distributing transmission and shafting and comprising a compressor, an expansion turbine, and a blower for supplying cooling air, there being a connection from the compressor of the air-conditioning unit to the main engine to supply compressed air for starting of the main engine.

In this way the excess output of the expansion turbine of the air-conditioning unit can be turned to account and the compressor of the auxiliary engine does not have to be designed to supply bleed air to the main engine when the aircraft is on the ground. Provision may be made for supplying compressed air to the auxiliary gas turbine engine when the aircraft is on the ground or in flight either from the main engine or from a ground-based compressor, without injection of fuel, and for regulating the supply of compressed air to control the speed of the auxiliary engine.

The aircraft auxiliary components are preferably mounted on a common support with the power-distributing transmission to form a power supply pack. In a multi-engined aircraft each main engine can have an associated power supply pack and this can be accommodated at any convenient location in the aircraft. This leads to improved accessiblity and serviceability for the auxiliary components and these can be driven at a constant speed by the auxiliary engine, avoiding the need, for example, for a rotational speed control unit for an electric generator forming one of the auxiliary components.

The provision of an emergency power pack, which may consist of a gas generator/turbine unit, a compressed air

turbine, an electric generator and/or a hydraulic pump will allow power to be maintained in one or both power supply systems in the event of breakdown of all the main engines.

Preferably the or each auxiliary engine is mechanically connected by means of a shiftable coupling, for example a shiftable free-wheel, and gearing to an emergency power turbine in such a way that the emergency power turbine can take over on the one hand the starting-up of the auxiliary engine and on the other hand the drive of the aircraft auxiliary components. Such an arrangement gives better operational reliability especially in regard to the possibility of starting up the auxiliary engine by means of the emergency power turbine.

When there are two auxiliary engines with associated power-distributing transmissions, a connecting shaft preferably including a clutch may be provided between the two transmissions. This has the advantage that is one auxiliary engine breaks down, the auxiliary components dependent on that engine continue to be driven by the engine which is still running. If the connecting shaft between the transmissions has a safeguard against overload in the form of a slipping clutch or a preset breaking point, this prevents destructive damage on one side of the connecting shaft when there is a stoppage on the other side. The insertion of a clutch or a slip coupling between the two sides allow the two transmissions to be coupled together either rigidly or with slippage, or of separating them.

Preferably the compressor, expansion turbine, and blower of the air-conditioning unit are connected to the auxiliary engine and/or to each other by way of clutches or slip couplings.

The invention will now be described in more detail, with reference to the accompanying drawings, in which Figure 1 shows schematically an aircraft power plant in accordance with the invention, and Fig. 2 shows a modified form of the power plant of Fig. 1 with a mechanical interconnection of the auxiliary engine, the power supply pack driving the auxiliary components, and the emergency power pack.

As shown in Fig. 1 a main gas turbine engine 1 for propulsion of the aircraft is associated with an auxiliary gas turbine engine 2 which by way of a power-distributing transmission 3 drives aircraft auxiliary components including an electric generator 4, hydraulic pumps 5 and 6, and a fuel pump 7. The components 4 to 7 are mounted on a common support with the transmission 3 to form a power supply pack 8. A connecting shaft 9 couples the transmission 3 of the power supply pack 8 to a transmission 3′ of a similar power supply pack 8′ which is driven by a second auxiliary engine associated with a second main engine, neither of which are shown in the drawing. The shaft 9 includes a clutch or slip couplings (not shown) so that, when required, power can flow from one power supply pack to the other. The connecting shaft 9 has an anti-overload safeguard, also not shown, which can consist of a slipping clutch or a preset breaking point. Thereby in the case of stoppage on one side of the shaft, destruction of components or gearing on the other side is avoided.

The power-distributing transmission 3 has an output shaft 10 on which are mounted a compressor 11, an expansion turbine 12, and a blower 13 of an air-conditioning pack 17. The components 11, 12 and 13 could also be mounted on separate shafts connected with each other and with the transmission 3 by way of clutches or slip couplings. The air-conditioning pack includes a heat-exchanger 14 to which cooling air is supplied by way of a line 15. The cooling air is drawn from the atmosphere by the blower 13, at least when the aircraft is on the ground, but may be forced through the heat exchanger 14 by ram action during flight, thus saving the power necessary for driving the blower.

The compressor 11 which is driven by the shaft 10 is interposed in an air intake line 16 which takes in atmospheric air or ram air.

For starting the main engine 1 compressed air from the compressor 11 is delivered by way of the line 16, a line 21 and a line 19 containing a shut-off valve 24 to the main engine either to act directly on the turbine blades of the main engine 1 or to operate a separate starter-air turbine. When the main engine is running compressed air from the compressor of the main engine is fed by way of a bleed line 18 controlled by a non-return valve 23 either to the combustion chamber of the auxiliary engine 2 or by way of a branch line 20 to the compressor of the auxiliary engine.

The air conditioning of the aircraft cabin can be achieved in various ways. With the main engine 1 running, compressed air from the main engine can flow from the line 18 by way of the line 21 through the heat exchanger 14 and the expansion turbine 12 to the cabin. The air is thus cooled by heat exchange and then further cooled by expansion before reaching the cabin and the turbine 12 delivers power to the shaft 10. Compressed air for air conditioning can also be supplied by the compressor 11 by way of the line 16 and when the aircraft is on the ground and the

main engine 1 is not running this provides all the air-conditioning.

It is an advantage of the arrangement described that the auxiliary engines can be operated on compressed air bled from the main engine not only at high flight altitudes but also at lower altitudes or even before the aircraft takes off. In the latter case it is not necessary to switch over to air-bleed operations at higher altitudes and this avoids interference with steady running and eliminates a possible source of trouble.

In case of emergency one or both of the auxiliary engines can be connected by way of a line 22 and shut-off valves 25 and 26 to an emergency power pack 27. This consists of an emergency power unit 28, a compressed air turbine 29, an electric generator 30, and if required a hydraulic pump 31. The unit 28 can for example comprise a turbine and a gas generator which (independently of atmospheric air) generates high-pressure gas for operation of the turbine from an energy carrier such as monofuel hydrazine.

Referring now to Fig. 2 corresponding parts have the same reference numerals as in Fig. 1. Between the auxiliary engine 2 and the power-distributing transmission 3 there is now interposed an accessory carrier 32 which carries the emergency power unit 28, the electric generator 30, and the hydraulic pump 31. The power unit 28 is always connected mechanically to the generator 30 and pump 31 by way of shafts 35 and 36 carrying meshing gear wheels 37 and 38. The gear wheel 38 is constantly in mesh with a gear wheel 39 which is carried on a shaft 34 and can be coupled to the shaft 34 by a shiftable free-wheel 33. The free-wheel 33 is so constructed that in a first position the gear wheel 39 can drive the shaft 34 but the shaft 34 cannot transmit torque to the gear wheel 39, whereas in a second position the gear wheel 39 is disconnected so that even when driven it can rotate freely on the shaft 34. Instead of the free-wheel 33, a shiftable coupling can be provided to connect and disconnect the wheel 39 and the shaft 34. It is also possible to arrange a coupling or clutch between the shaft 34 and the transmission 3 so that the entire power supply pack 8 can be disconnected from the shaft 34. A further possibility would be to mount the emergency power unit 28, the generator 30 and the pump 31 directly on the same support as the transmission 3, the latter being directly coupled to the auxiliary engine 2 while power unit 28 is connected to the auxiliary engine by way of a free wheel and gear wheels.

The mode of operation of the arrangement shown in Fig. 2 is as follows. If the auxiliary engine 2 is running, in order to start the main engine by the supply of compressed air from the compressor driven by the shaft 10 or to actuate the power supply pack 8, then the shaft 34 rotates relative to the stationary gear wheel 39, the emergency power unit 28 being out of operation. The free-wheel 33 is then in its first position, in which no torque is transmitted from the shaft 34 to the gear wheel 39. If the auxiliary engine 2 is out of action and is to be restarted, the emergency power unit 28 can be started up by generating gas from the hydrazine monofuel to drive the auxiliary devices 30 and 31 and the gear wheel 39. With the free wheel 33 still in its first position the gear wheel 39 drives the shaft 34 to start up the auxiliary engine 2. During this operation the resistance to start up can be reduced by uncoupling the transmission 3 from the shaft 34. If the auxiliary engine 2 cannot be restarted and in consequence the power supply from the power pack 8 fails, the free-wheel 33 is moved to its second position and the emergency power unit 28 driving the devices 30 and 31 provides emergency power. The gear wheel 39 then rotates freely on the shaft 34. With a disconnectable coupling instead of the free-wheel 33 the same mode of operation can be achieved, the desired coupling and uncoupling of the shaft 34 and gear wheel 39 being effected from time to time by a switching operation.

In the embodiments described each auxiliary engine normally generates power by using compressed air bled from the compressor of the main engine and increasing the energy content of this air by burning injected fuel in the combustion chamber of the auxiliary engine. The rate of rotation of the auxiliary engine is mainly controlled by metering of the fuel feed to the combustion chamber. It is desirable that the auxiliary engine should be capable of functioning without fuel injection in order to maintain the drive of the aircraft auxiliary components and to supply air for starting of the main engine.

For the former purpose the auxiliary engine can be driven by compressed air from the main engine while the aircraft is in flight. On the ground the supply of compressed air to drive the auxiliary engine can be obtained from a compressor outside the aircraft. In each case regulating apparatus is installed in the compressed air feed line to control the rate of rotation of the auxiliary engine.

By this means it is possible, when faults arise in flight, to keep the auxiliary engine running at reduced power by means of bleed air alone. It is also possible to start the main engine by supply of compressed air to the turbine stage of the auxiliary

engine if, for example, the starting equipment of the auxiliary engine is defective. The operation of the auxiliary engine as a compressed air turbine fed with air from a compressor on the ground is also of advantage if the auxiliary engine must not emit injurious effluent gas, for example when the aircraft is in a hangar. It is furthermore advantageous during the aircraft testing phase because the auxiliary engine is operated at a lower temperature and its life is thus prolonged.

WHAT WE CLAIM IS:—

1. Aircraft power plant comprising at least one main gas turbine engine for propulsion of the aircraft, an auxiliary gas turbine engine having a connection to the main engine to receive compressed air from the main engine, a power-distributing transmission coupled to the auxiliary engine, aircraft auxiliary components connected for drive by the auxiliary engine through the power-distributing transmission, and an air-conditioning unit drivable by the auxiliary engine through the power-distributing transmission and shafting and comprising a compressor, an expansion turbine, and a blower for supplying cooling air, there being a connection from the compressor of the air-conditioning unit to the main engine to supply compressed air for starting of the main engine.

2. Aircraft power plant as claimed in claim 1 in which the aircraft auxiliary components are mounted on a common support with the power-distribution transmission to form a power supply pack.

3. Aircraft power plant as claimed in claim 1 or 2 comprising a plurality of main gas turbine engines, at least two auxiliary gas turbine engines and a power-distributing transmission associated with each auxiliary engine, the two transmissions having a connecting shaft between them.

4. Aircraft power plant as claimed in claim 3 having a clutch in the connection between the two transmissions.

5. Aircraft power plant as claimed in any of claims 1 to 4 in which the compressor, expansion turbine, and blower of the air-conditioning unit are connected to the auxiliary engine and/or to each other by way of clutches of slip couplings.

6. Aircraft power plant as claimed in any of the preceding claims having an emergency power pack comprising a gas generator/turbine unit, a compressed-air turbine, and an electric generator.

7. Aircraft power plant as claimed in any of claims 1 to 5 in which the or each auxiliary engine is mechanically connnected by means of a shiftable coupling and gearing to an emergency power turbine in such a way that the emergency power turbine can be used to start up the auxiliary engine and to drive the aircraft auxiliary components and the air-conditioning unit.

8. Aircraft power plant as claimed in any of the preceding claims wherein provision is made for supplying compressed air to the auxiliary gas turbine engine when the aircraft is on the ground or in flight either from the main engine or from a ground-based compressor, without injection of fuel, and for regulating the supply of compressed air to control the speed of the auxiliary engine.

9. Aircraft power plant substantially as described with reference to Fig. 1 of the accompanying drawings.

10. Aircraft power plant substantially as described with reference to Fig. 2 of the accompanying drawings.

REDDIE & GROSE
Agents for the Applicants,
6, Bream's Buildings,
London EC4A 1HN.

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1467681 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

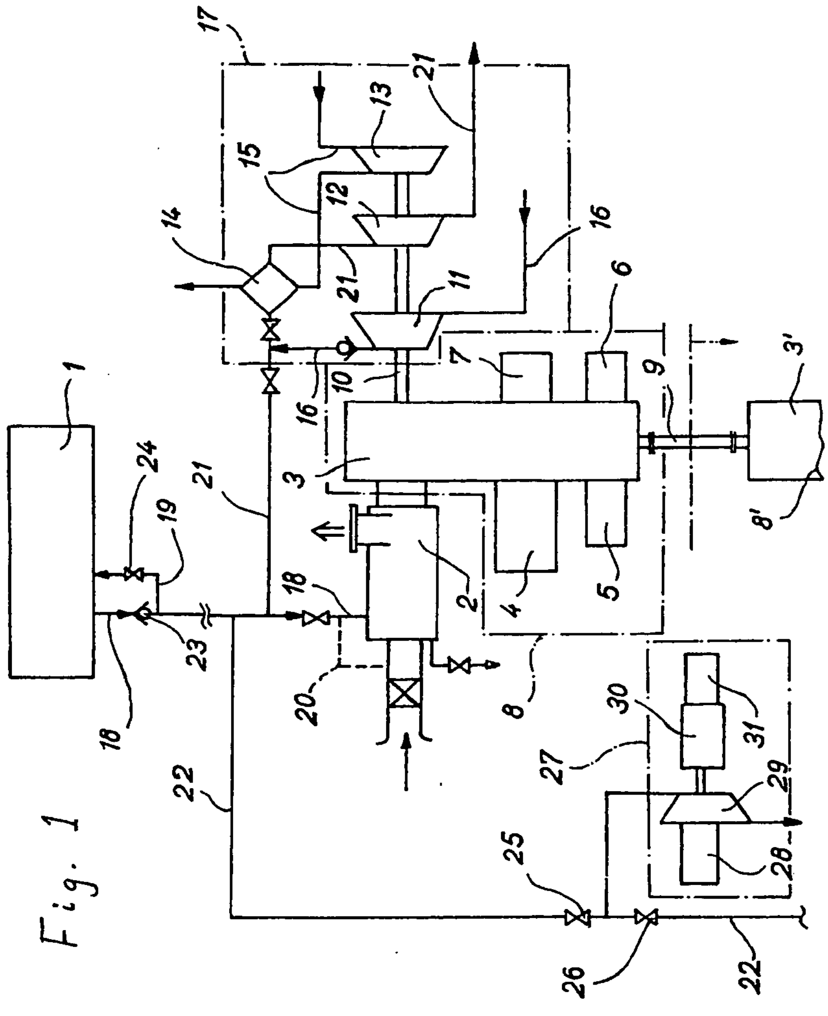

Fig. 1

1467681 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

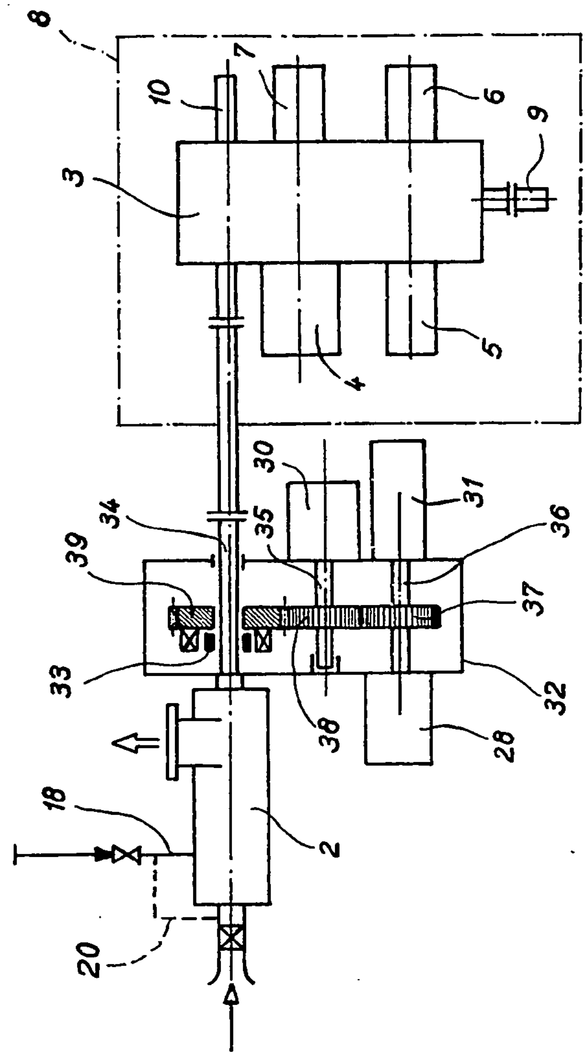

Fig. 2